

THE IMPACT OF FLUORESCENT AND LED LIGHTING
ON STUDENT ATTITUDES AND BEHAVIOR IN THE CLASSROOM

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ABSTRACT

RESEARCH PAPER: The Impact of Fluorescent and LED Lighting on Student Attitudes and Behavior in the Classroom

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This study examined empirical research on the effects of high correlated color temperature light-emitting diodes (LED) and fluorescent lighting on students in the classroom. LED are becoming the most recent lighting option for optimal energy efficiency over fluorescent technology. A review of the literature indicates correlated color temperature (CCT) of lighting has non-visual effects on students, with higher CCT positively impacting attitudes and behavior. The review also revealed current studies regarding dynamic or tunable lighting that adjusts CCT based on desired activity and mood. Data from an original survey analyzed teacher insights and perceptions regarding student attitudes and behaviors associated with existing classroom lighting and the impact of higher color temperature LED. Participants were qualified teachers of levels pre-K through high school from three schools and personal contacts of the principal investigator. Seventy-five teachers responded to the online questionnaire. The survey data suggests teachers perceive higher color temperature lighting positively impacts student alertness, attitude, and energy level; and adjusting light levels throughout a school day positively impacts student engagement. Results were mixed regarding the impact of higher color temperature and on-task behaviors, with no significance suggested that fluorescent lighting impacts off-task behaviors.

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CHAPTER 1

INTRODUCTION

Introduction

Lighting within the built environment is an important factor on human development and functioning. Research has shown that daylight can impact human mood, performance, and well-being; including children and schools. According to Wurtman “Light is the most important environmental input, after food and water in controlling bodily functions.” (Wurtman, 1975) However, daylight must be supplemented with artificial lighting and today’s society is exposed to more artificial light than daylight. (Veitch, 1995) For many years fluorescent lighting has been the solution to provide energy efficiency and high illuminance for school environments; and have evolved to include full-spectrum lamps that simulate daylight. Recently, LED (light-emitting diodes) have come to the forefront due to their efficiency, longevity, and ability to provide a full, smooth, unbroken spectrum.

Studies have shown a major increase in positive perceptions and behavior within the work and classroom environment when incorporating LED fixtures with higher correlated color temperatures (CCT); specifically, positive engagement and increase in on-task behaviors. The implementation and effects of dynamic and tunable lighting is still being studied as to its long-term implications, however, when examining focus and concentration, Mott, et al (2012, 2014)

and Slegers, et al (2012) support the theory that high kelvin LED lamps can have a positive effect. Grangaard (1995), Knez (1995), Smolders & de Kort (2016) and Hawes, et al (2011) all implemented laboratory studies with results supporting the theory that high correlated color temperature (CCT) has positive effects on cognitive performance and on-task/off-task behaviors. Hawes, et al (2011) specifically compared fluorescent and LED lamps which indicated better perceived performance and arousal states with high CCT LED lamps.

Our children are expected to attend school to learn and perform at optimum levels. It's imperative to provide artificial lighting that enhances the classroom experience for children and teachers, enables strong cognitive function, and supports positive behavior.

Statement of the Problem

Providing lighting that supports the various needs within a classroom continues to be a struggle and studies show that student behaviors and performance are impacted by classroom lighting. Fluorescent lamps have been the standard choice for school systems to provide efficient, quality lighting; however, LED lamps with higher correlated color temperatures (CCT) are the most recent high efficiency lamps to be integrated into the built environment and more studies are evaluating their positive impacts. The goal of this study is to provide insights for designing classroom lighting that positively impacts student attitudes and behavior.

Purpose

The purpose of this study is to examine insights and perceptions regarding attitudes and behaviors associated with classroom lighting, specifically the impact of fluorescent versus LED high correlated color temperature (CCT) lighting on students. The learning objects include perceptions regarding: 1) impact on positive mood, attitudes, and alertness of students, 2) impact on student engagement and on-task/off-task behaviors and 3) impact on student well-being.

Research Question

Findings from existing literature suggest that lighting interventions within the built environment can affect behaviors, performance, and well-being of humans. It is hypothesized that higher color temperature LED lighting within a classroom positively impacts perceived attitudes and on-task behaviors of students.

Rationale

This study aims to obtain teacher insights and perceptions of classroom lighting based on their existing classroom situation and experience. Data from an original survey will examine perceptions of teachers and how lighting in the classroom impacts student attitudes and behaviors. It is expected that the survey data will support the theory that high correlated color temperature lighting positively impacts student on-task behavior and attitudes; supporting the need for further research within a controlled environment, which examines the impact of fluorescent lighting versus LED on students.

Assumptions

The questionnaire was implemented via Qualtrics and it is assumed all respondents met the introductory listed participation requirements, were truthful, and interpreted the directions and questions similarly. For questions that included images of classrooms, it is assumed the respondent focused on the light source illustrated versus architectural design and finishes of the classroom.

Definition of Terms

The two forms of lighting discussed within this study are fluorescent and LED. Fluorescent for purposes of this study is referring to a tube fixture technology. LED stands for light-emitting diodes. Correlated color temperature (CCT) is measured in Kelvin (K) and is a

factor that is critical to the color of light seen within the built environment; i.e.: warm or cool. For the purposes of this paper the terms correlated color temperature (CCT) and Kelvin will be used interchangeably. High CCT is defined as 4200K or higher. The color rendering index (CRI) refers to a light sources ability to show an objects color realistically. These terms are further described and discussed within the literature review.

Non-visual effects within this study will focus on three of the five categories described by Woolner (2007) and include 1) *Engagement*: levels of attention and on-task behaviors; 2) *Health and Well-being*: impacts on the physical self, discomfort, or ailments; and 3) *Affect*: attitude, mood, and motivation. Knez (1995) defines Positive Affect (PA) as reflecting mood and motivation as to whether a person feels enthusiastic, active, or alert. On-task behavior within a classroom is defined as: student engagement for a given amount of time that matches the current classroom instruction. Grangaard (1995) defines student off-task behavior as 1) not visually following the lesson; 2) appears to be attentive but playing with objects; 3) moving chair or body precluding ability to concentrate on lesson; 4) appears to be daydreaming, not involved; 5) bothering children around them; 6) overtly acting out, not attending to lesson.

Summary

Lighting plays a major role in supporting learning and behavior within the classroom. There has been an expanse of past research examining the non-visual effects of lighting on humans, with the majority focused on fluorescent technology. However, recently more studies are evaluating the impact of LEDs, which are the newest energy efficient light source. Federal and state energy conservation requirements have forced schools to meet and implement high efficient lighting solutions which has expanded the use of LED fixtures. The downside has been the cost to retrofit or implement LEDs within the school environment. Many existing school

systems utilize fluorescent 3200-3500 Kelvin lamps and when retrofitting with LED there is inconsistent evidence as to what kelvin temperature should be implemented. This study reviews current literature regarding the impact of fluorescent lighting and LED and implements a teacher survey that examines perceived emotional and behavioral effects of higher correlated color temperature LED versus fluorescent lighting on students in the classroom.

CHAPTER 2

LITERATURE REVIEW

The purpose of this study is to understand the non-visual effects and perceived impact of fluorescent versus LED high correlated color temperature lighting on student attitudes and behavior in the classroom. The following literature review evaluates fluorescent lighting and LED with regards to their impact on energy efficiency, health and well-being, and human behaviors and attitudes. Fluorescent and LED are the industry standard lighting solution used within school environments to meet these expectations. Research continues to try and fully understand how these lamps affect humans and the built environment.

Fluorescent, LED, and Correlated Color Temperature Overview

Fluorescent technology has evolved from warm and cool to full-spectrum color rendering. The color rendering index (CRI) scale is from 0-100 and excellent color rendering is at values over 76, with pure sunlight at a CRI of 100. The correlated color temperature (CCT) is also a critical measurement when evaluating light sources and is measured in Kelvin (K); 3500K and below provides a red/yellow warm, 4000 - 5000K neutral/white, 5500 and above blue/violet cool (LED Corporations, 2012) (refer to Figure 2.1). A temperature of 3200K – 3500K continues to be the lamp of choice for many classroom environments. Illuminance is also a measurement factor to ensure the recommended brightness level for various built environments and activities.

The Illuminating Engineering Society (IES) recommends the light level for classroom desktops to be 60 foot-candles (fc).

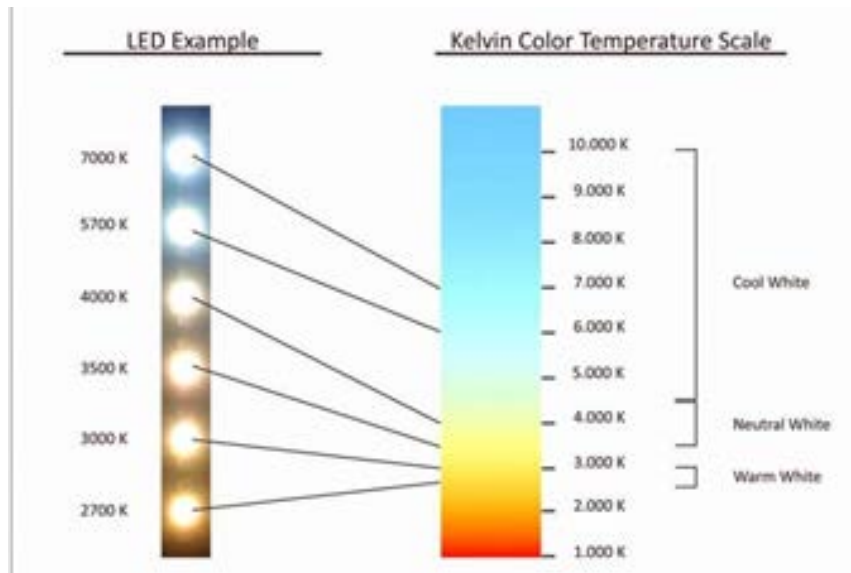


Figure 2.1 LED Lighting Kelvin Color Temperature Scale Chart, Source (LED Corporations, 2012)

Fluorescent and LED both have the capability of meeting the various light out-put and coloring needs, however, there are advantages and disadvantages. Fluorescent lamps use phosphor coatings to improve color perception, such as full-spectrum fluorescent which emulates daylight and diffuse UV radiation. They also contain mercury which can be toxic and need to be disposed of appropriately so not to induce health risks (Havas, 2008).

LEDs can produce more light per watt than many fluorescents lamps, therefore having a higher efficiency. Visible light is created by an electrical current passing through a microchip. They radiate very little heat and typically have a longer useful life. Instead of “burning out” like other light sources, LEDs dim slowly over time creating “lumen depreciation.” They can be dimmed and turned on and off quickly. They also use phosphor coatings to convert colors to white light, however, they do not contain gaseous toxins. High color rendering can also be

achieved with LEDs without requiring more power due to using fewer lumens while still producing light that is affective for people to work and function. (Papamichael, et al, 2016). Although, LEDs are still priced higher in the market than fluorescents, this is slowly starting to change with new developments and life cycle cost analyses continuing to be evaluated (Cowan & Daim, 2011).

Behavioral Categories

Reducing energy is an important factor for both environmental and economic reasons. However, lighting technology needs to be evaluated on its benefits and expectations beyond reduction of energy supply and costs. When designing a built environment to impact learning there are several categories that are addressed and evaluated. These are considered *non-visual effects* and include: 1) *Attainment*: improvements in curriculum attainment measured by standardized tests or exams, or as monitored by teacher observation. 2) *Engagement*: improvements in levels of attention, more on-task behaviors observed, decrease in distracted or disruptive behavior. 3) *Affect*: improvements in self-esteem for teachers and learners, increased academic self-concept, improvements in mood and motivation. 4) *Attendance*: fewer instances of lateness or absenteeism. 5) *Health or Well-being*: impacts on the physical self, relating to discomfort as well as minor major ailment (Woolner, 2007).

Cowan and Daim (2011) established four behavioral categories for evaluation: 1) performance expectations (fitness for purpose); 2) Effort Expectancy (ease of use/operation); 3) Social Influences (norms and image); Facilitating Conditions (compatibility/perceived behavioral control). Veitch and Newsham propose a behaviorally based evaluation of the quality of lighting into six categories: 1) visual performance; 2) post-visual performance; 3) social interaction and

communication; 4) mood state; 5) health and safety; 6) aesthetic judgement (Veitch & Newsham, 1997).

Non-Visual Effects: Health

Research supports that lighting systems can have non-visual effects on humans when exposed over long periods of time. Hathaway (1992) conducted a two-year study that evaluated full spectrum fluorescent (FSPF), FSPS with ultraviolet light supplements, cool white fluorescents, and high-pressure sodium and the effects on students' dental, growth and development and attendance histories. There was found to be less dental decay, greatest height and weight gains, and better attendance and academic achievement for students receiving UV light supplements versus those who were in the non-UV group. Groups under sodium vapor lighting had the slowest and lowest rates in all categories (Hathaway, 1992).

Other health risks continuing to be researched are radio frequency radiation and ultraviolet radiation of compact fluorescents (CFL) and tube fluorescent (T8 and T12). People with electro-hypersensitivity can be affected by various types of lighting. Irlen syndrome or scotopic sensitivity syndrome are spectral disorders that have been associated with broken color fluorescents or spikes of green/orange/magenta that cause sensory overload. Symptoms can include headaches, dizziness, nausea, eye strain and burning, and in extreme cases seizures, cardiac and respiratory issues (Havas, 2008). A survey by Havas indicated self-proclaimed electro-hypersensitivity (moderate to extremely sensitive) to be highest for headaches when exposed to both tube and compact fluorescent and lowest with LED (Havas, 2008).

Light flicker can occur in fluorescent and LED lamps and is defined as the rapid and repeated change in light brightness or intensity, typically occurring at 120Hz modulation. Flicker may or may not be visible to the human eye. Many studies have found that normally functioning

fluorescents can be a source of flicker and have biological effects such as a general feeling of discomfort, illness, headaches, eye strain (IEEE, 2010) and reduced speed of visual search and performance (Veitch & McColl, 1995). This can occur in fluorescents due to voltage fluctuations, dimmer switches, and type and age of ballast. LED can also have visible and non-visible flicker, however with the appropriate frequency and modulation depth, can be flicker-free (IEEE, 2010).

Non-Visual Effects: Behavior and Performance

Lighting and the non-visual effects on behavior, and performance have been studied in relation but not limited to color rendering, mood, focus, cognitive performance, alertness, and visual acuity. Many of these studies are based in theoretical research of our body's natural clock, or circadian rhythm which regulates our sleep/wake cycle; our body responds/awakens to bluish light as experienced in morning hours, and warmer light causes the brain to release melatonin which prompts us to relax and prepare our bodies to sleep. (Govén, et al, 2009; Kuller, et al, 2006).

Knez (1995) evaluated mood and cognition of ninety-six subjects ages 18-55. Two studies were implemented within an experimental room setting. All planes of the room and furnishings were neutral in color, and there were no windows. The independent variables for Experiment 1 were: 2 illuminance levels (300 lx vs 1500 lx); 2 color temperatures (3000K vs 4000K); each at a high CRI 95; and 2 genders, totaling four lighting conditions per gender. Dependent variables included cognitive tasks including problem solving, free recall, and performance appraisal; plus, mood and room light evaluation measures based on PANAS (Positive Affect Negative Affect Scales). Positive Affect (PA) reflects whether a person feels enthusiastic, active, alert; where Negative Affect reflects distress or unpleasantness. A 5-point

unipolar Likert scale of seven questions was used to evaluate the room's light: glaring, dim, soft, bright, warm, intense, cool. Experiment 2 was implemented identical to the first except for using a low CRI 55. The results indicated that the color temperature and illuminance that induced a positive mood enhanced performance in problem solving and free recall tasks. The subjects' mood and their cognitive performance varied significantly between genders, indicating that genders emotionally had different reactions to the color temperature (Experiment 1) and combinations of color temperature and illuminance (Experiment 2) at different CRIs (Knez, 1995).

Past lighting research has indicated that light sources with good color rendition are preferred over those with poor color rendering properties, and perceive that objects appear more clear and sharp. Studies continue to establish evidence of the importance of accuracy of color rendering and the contribution that color perception makes to visual performance. Veitch & McColl's study (2001) supports lamps having color temperature of 4000K and high CRI provide visual clarity. As cited by Hawes (2010), Knez and Kers (2000) found that younger adults elicit a negative mood in warm versus cool fluorescent lighting while working on cognitive tasks and Mills et al. (2007) illustrated that very high color temperature fluorescent lighting in the workplace can enhance alertness, reduce fatigue, and increase productivity. Hoffmann et al. (2008) demonstrated that 6500K compared to 4000K enhanced levels of arousal and concentration (Hawes, 2010).

Grangaard studied the effects of color and light on the behaviors of six-year old children in the classroom environment. Grangaard states, "It is said that the environment educates because the learner interacting with the environment will be more or less motivated, more or less productive as determined by the elements of his environment" (Grangaard, 1995). An ABA

method included three phases where color and light were manipulated. First phase was the original classroom environment of orange and white walls and cool-white fluorescent lamps; second was the test phase with light blue walls, full-spectrum fluorescent; and the third was changed back to original environment in phase one. Each phase lasted ten-days, children were video-taped for 15 minutes same time in the morning and afternoon; and the children's blood pressure was also taken same time morning and afternoon. Three educators were trained to count off-task behaviors identified on the video tape. Off-task behaviors included the child: 1) is not visually following the lesson; 2) appears to be attentive but playing with objects; 3) moving chair or body precluding ability to concentrate on lesson; 4) appears to be daydreaming, not involved; 5) bothering children around them; 6) overtly acting out, not attending to lesson. There was a 22% decrease in off-task behaviors during Phase 2 where only the wall color and fluorescent lamps were manipulated (Grangaard, 1995).

Smolders & de Kort (2014) studied the effects of correlated color temperature (CCT) on alertness and vitality in the morning vs afternoon. A multi-measure approach was utilized to examine the effect of 2700K vs 6000K fluorescent lamps, with 500 lx (45.5 fc) on desktop. Thirty-nine students participated in the laboratory study and came on two separate days. In one session they were exposed to 2700K and the other to 6000K. Morning and afternoon sessions were scheduled at the same time of day. There was no daylight in the room. Subjective sleepiness, energetic/arousal, tension, mood, and self-control were measured using the Karlinkska sleepiness scale (KSS; Akerstedt & Gilberg, 1990); Activation-Deactivation checklist (Thayer, 1989); energy and arousal used four items (energetic, lacking in energy, alert, sleepy). Tension consisted of two items (tense and calm). Positive affect and negative affect were measured by single item (happy and sad). All response scales were a 1-4 "definitely not" to "definitely". The

self-control response measure used a 7-point Likert scale. Four different task performances were assessed. A baseline performance was measured using 4000K along with a short questionnaire prior to initiating three repeated blocks of 20-minute sessions where the lighting was changed from 2700K or 6000K. Results were mixed indicating higher energy/arousal under 6000K in the morning, but no significant effects in the afternoon. Participants rated both mood and the light settings as less positive in the 6000K vs 2700K. The findings highlight that a person's current psychological state of fatigue may play a role in how they respond to bright light during the day and that further research and development of dynamic and personalized lighting systems may assist with alertness and mental well-being.

Non-Visual Effects: Studies using LED versus Fluorescent

The effects of lighting on humans have focused on fluorescent lamps over the last several decades, however, more recent studies are examining LEDs and their effects on the work and classroom environments, including dynamic or tunable lighting.

Ferlazzo et al. (2014) studied the effects of LED light sources on participant performance of visual spatial abilities and executive functions. A specifically designed environment with fully controlled light was used to study forty-four college students with a mean age of twenty-five point six. 2800K halogen lamps vs 4000K LED lamps were implemented in the experimental cabin. Results suggested that cooler light exposure improves cognitive abilities to deal with multiple tasks or task switching, creating fewer errors in the mental rotation of 3-D objects.

Hawes, et al. (2011) studied LED versus fluorescent and their effects on worker performance. They hypothesized that lower color temperature would be associated with low arousal or sleepiness and negative mood, versus higher color temperature; therefore, causing slowed response during the performance of two cognitive tasks. Twenty-four subjects

participated using a repeated-measures design that required participants to visit the laboratory on five consecutive days. Four lighting systems were implemented: 1) traditional fluorescent with an average color temperature of 3345K; 2) LED 1 with an average color temperature of 4175K; 3) LED 2 with an average color temperature of 5448; and 4) LED 3 with an average color temperature of 6029K; the general illumination was 32.6-foot candles. The Farnsworth-Munsell 100 color hue test was used for two color recognition tasks; the Adapted Snellen Eye chart was used for the visual acuity task; two different cognitive tasks were implement after a 15-minute passive cognitive task allowing participants to adapt to the lighting conditions. The Profile of Mood States (POMS) questionnaire using a 5-point scale measured mood assessment. The repeated-measures analyses of variance (ANOVAs) were used to identify main effects of the lighting conditions, followed by using paired t-tests. Effect sizes were indicated using eta-squared for the ANOVAs and Cohen's d for the t-tests. The study found four main results: 1) visual perception of color recognition showed faster performance with lighting of higher color temperatures; 2) higher color temperatures generally led to increased state of arousal and lower color temperature led to lower rated depression; 3) one verbal and one spatial cognitive task showed faster reaction times with higher color temperature; and 4) evidence indicates lighting induced improvements in participant mood predicting faster cognitive performance. The study indicates that LED at higher color temperatures supports positive mood, wakefulness, and speed in performance of visual perception and cognitive tasks relative to traditional fluorescent at lower color temperature (Hawes, 2011).

Mott, et al, (2012) studied the effects of high intensity, glare free lighting (referred as focus light setting) increased third grade student's oral reading fluency. Eighty-four third graders were exposed to fluorescent focus lighting (6000K at 1000 lux) or fluorescent normal lighting

(3500K at 500 lux). This was a quasi-experimental design using four randomly assigned classrooms. A motivational questionnaire was executed adapted from Pintrich and Degroot (1990) for third grade level. A d2 Test of Concentration (Brickenkamp & Zilmer, 2010) was used to measure student ability to concentrate. The test takes approximately eight-minutes to administer and has an internal consistency above .90. The results found no effects of lighting on motivation, however, focus lighting of 6000K led to a higher percentage increase in oral reading fluency performances versus the control lighting (Mott, et al. 2012). A new study by Mott, et al in 2014 examined the use of three preset lighting settings: 1) focus, 2) calm, 3) normal, over an entire academic year of at-risk third grade students. Similar findings during this study occurred as the first study in which the focus lighting students increased their oral reading fluency scores at a greater rate than the normal lighting students.

Sleegers, et al., (2012) implemented three studies to evaluate dynamic lighting within children's classrooms. Dynamic or tunable lighting is a newer concept that allow the user to adjust the color temperature and illuminance via different lighting settings throughout the day. These different settings can be applied to support alertness and relaxation and are defined by Sleegers as Energy (12000K); Focus (6500K); Calm (2900K); and Standard (3000-4000K). Sleegers, et al., evaluated LEDs at different Kelvin temperature and their effect on concentration and gender performance. There were three studies, Study 1 and 2 were pre-test/post-test nonequivalent control groups. Study 1 used two schools consisting of a control group using conventional luminaires with a correlation color temperature (CCT) of 4000K and no dynamic lighting. The experimental group classroom used dynamic lighting with focus setting of 6500K during concentration tests; and standard, energy and calm settings throughout the remainder of

the day. Study 2 used two classrooms with one assigned the control setting and one the experimental setting. The control group classroom was equipped with fluorescent T8s at a CCT of 3000K, and the experimental group classroom with LED 3000K for pre-test and 6500K post-test. Study 3 implemented a post-test only control group within a windowless lecture room. A researcher manipulated the lighting system between standard (3000-4000K) and focus (6500K). All three studies found on average that concentration performance increased in the experimental groups. Results also indicated improved concentration may be based on grade level, with grade 4 students more affected than grade 6. There were mixed results based on concentration performance of gender when comparing statistics from each study (Slegers, et al, 2012).

Various other studies have examined how the built environment can affect children in the classroom. Dr. Shireen Kanakri, et al. (2017) explored empirical research regarding the impact of noise on children with Autism Spectrum Disorder (ASD). Based on the research, a survey was developed to gain teacher insight and perceptions regarding the impact of acoustics and lighting on behaviors of children with ASD. Results from the survey established a ranking of the most influential acoustical factors on autistic behavior and established the basis for the second phase of the study. Results were evaluated using the t-test, chi-square, and descriptive statistics. The descriptive method was used to organize data in tables and graphs, with total scores and distribution of percentages. Inferential statistics used samples of the data to establish general statements and conclusions regarding participants thoughts and insights (Kanakri, et al, 2017). The second phase was an observational study using a high definition video camera and behavioral recording software to evaluate differences in behavior and noise levels in classrooms. (Kanakri, et al., 2016). Kanakri is currently studying the effects of lighting on the behavior of

children with autism. A survey was developed for teachers and parents using attitude, Likert, semantic differential, and rating scales. Questions and images of school classrooms assessed participant insights and perceptions. A pilot study observed five children with high functioning autism, ages 6-8 years old, within the Ball State University Health Environments Design Research Lab. The same children were observed performing the same tasks within the controlled environment using fluorescent light and LED lighting. The results indicated a significant improvement of unwanted behaviors with the intervention environment of LED lamps.

CHAPTER 3

METHODS

Introduction

The purpose of this study was to receive insights from teachers regarding the impact of lighting on perceived student emotions, attitudes, and behaviors in the classroom, specifically the impact of fluorescent versus LED high color correlated temperature (CCT) lighting on students. This chapter provides information regarding the recruitment of teacher populations, sample size achieved, the survey instrument, validity/reliability, design and procedure for implementation, data analysis, and IRB approval.

Participants and Recruitment

Teacher populations were recruited through public and private schools, receiving permission from three school administrators or directors with Letters of Support. These schools included North Ridge Dallas Center-Grimes Elementary, Grimes, Iowa; Ball State University Child Study Center, Muncie, Indiana; and the Eman School, Fishers, Indiana. Recruitment also occurred from personally known, independent teachers not associated with the recruited school organizations. Participant requirements included having to be 18 years of age, have taught a minimum of 12 weeks in the classroom, teach between levels Pre-K through 12, are a full-time teacher, practicum teacher, teacher aide or full time building substitute teacher.

Sample Size

One hundred-ten teachers, levels Pre-K through 12, were provided the Qualtrics online survey link. There was a 68% response rate with 75 responses received, establishing a 95% level of confidence and a 6.5% margin of error.

Instrumentation

Survey research was implemented using an original questionnaire to obtain data regarding teacher insights and perceptions regarding classroom lighting and the impact on student attitudes and behaviors. (refer to Appendix B for questionnaire) Questions and terms used were generated as the result of sources from the literature review, specifically Kanakri, et al (2017) questionnaire developed for teacher insights regarding acoustics and lighting for children with autism; and behavior and lighting terms used in analysis by Mott, et al (2012) and Slegers, et al (2012).

The questionnaire consisted of twenty-three questions created in Qualtrics and was based in affective testing using attitude, Likert, semantic differential, and rating scales. Questions and images of school classrooms assessed teacher insights and perceptions of student engagement, affect, and well-being. These were clustered and analyzed for higher reliability. Questions included multiple choice, 5-point Likert, open-ended, and images of classrooms with fluorescent lighting and LED ranging from 3000 – 6500K.

Teachers were asked to provide demographic information regarding gender, number of years teaching, whether teaching in public or private school setting, and length of time teaching in current classroom location. They also were asked to complete multiple-choice questions regarding the type(s) of lighting and fixtures currently in their classroom (i.e., overhead fluorescent or LED, windows, skylights, desk lamps, etc.) as well as identifying the lens cover

types via images and descriptions. Multiple-choice questions were also utilized to obtain data regarding how and when teachers adjusted the light level within their classroom, including time of day and activity.

Multiple-choice 5-point Likert questions addressed perceived issues with light glare, flashing, flicker, brightness, and perceived student behavioral responses to lighting regarding attention, focus, and mood. A 10-point slider scale evaluated teacher insight and perceptions regarding student behavioral response to light fixture humming, intensity, brightness, and glare. The questionnaire also addressed teacher's perceptions of images illustrating the same classroom implemented with fluorescent versus LED and lower versus higher Kelvin temperature lighting. Teachers were asked to select between the two images as to which classroom they perceived best for behaviors of engagement and affect. (i.e., enhanced alertness, positive mood, encourage focus and staying on-task). Additional multiple-choice questions also addressed teacher perception of student engagement and affect in a classroom with 6500K, 4200K and 3500K LED lighting with choices of 1) sit and listen; 2) move and interact; 3) relax and rest; 4) none of the above. A final open-ended question was provided to allow for any additional comments and insights.

Design and Procedure

The questionnaire was implemented in Qualtrics and distributed through an online link. An introductory statement regarding the purpose of the survey, the IRB approval number, and participant qualifying factors were included. The survey was intentionally designed to require an average of ten minutes to complete for increasing potential of a high response rate.

Two of the three schools that provided Letters of Support resulted in high response rates. North Ridge Dallas Center-Grimes Elementary School distributed the survey during a teacher in-service day which resulted in a 100% response rate, twenty-seven of twenty-seven teachers. Ball

State University, Director of the Child Study Center, distributed to qualifying teachers via an email which resulted in a 73% response, eight of eleven teachers. The Eman School Behavior Specialist distributed the survey via email resulting in a 29.16% response rate, seven of twenty-four teachers. The Principal Investigator also had the survey distributed via email to a quantity of forty-eight teachers, who were personal contacts and independent of the recruited school organizations mentioned above. These individuals teach levels Pre-K through 12 in public and private schools in Florida, Kansas, Indiana, and Iowa. Thirty-three responses were received for a 68.75% response rate.

All data was collected and stored on Ball State University's Qualtrics site, secured with a password, and only available to the Principal Investigator and Faculty Advisor. Participant identities were kept anonymous and raw final data was securely maintained on a flash drive for analysis and support of future studies.

Data Analysis

Descriptive statistics were used to organize survey data in tables and graphs via Qualtrics and Excel. Total scores, distribution of percentages, mean and standard deviation were analyzed. Inferential statistics used samples of the data to establish general statements and conclusions regarding participants' thoughts, perceptions, and insights.

IRB Approval

The Institutional Review Board (IRB) reviewed the study research protocols, determining it to be exempt from further review based on Exempt Category 2. The study was approved and assigned IRB protocol #1213195-1.

CHAPTER 4

RESULTS

The purpose of this study was to receive insights from teachers regarding the impact of lighting on perceived student emotions, attitudes, and behaviors in the classroom, specifically the impact of fluorescent versus LED high correlated color temperature (CCT) lighting on students. The learning objectives included insights and perceptions regarding: 1) impact on positive mood, attitudes, and alertness of students, 2) impact on student engagement and on-task/off-task behaviors and 3) impact on student well-being. Survey results included data regarding participant demographics, existing classroom lighting; and insights and perceptions regarding impact of lighting on student affect (attitude, mood, alertness), engagement (attention, on/off-task behaviors), health/well-being; adjusting light levels during school day; and open comments.

Participant Demographics

One hundred-ten teachers, levels pre-K through 12, were provided the Qualtrics survey link. There was a 68% response rate with 75 responses received. Three schools provided Letters of Support. North Ridge Dallas Center-Grimes Elementary School had a population of 27 teachers with 27 responding. Ball State University, Child Study Center, distributed the questionnaire to 11 qualifying teachers with eight responding, and the Eman School had a potential population of 24 teachers with 7 responding. Forty-eight teachers, who were personal

contacts and independent of the recruited school organizations were recruited via email and resulted in 33 responses.

The gender of raters was significantly higher for female versus male with a quantity of 65 females (86.67%) and 10 males (13.33%). Most of the teachers responding had extensive experience teaching in the classroom, with 41 of the 75 teachers having 11 or more years (54.67%). A quantity of 14 (18.67%) indicated having 6-10 years of experience; 13 (17.33%) had 1-5 years; and 7 (9.33%) had under 1 year of experience (refer to Figure 4.1).

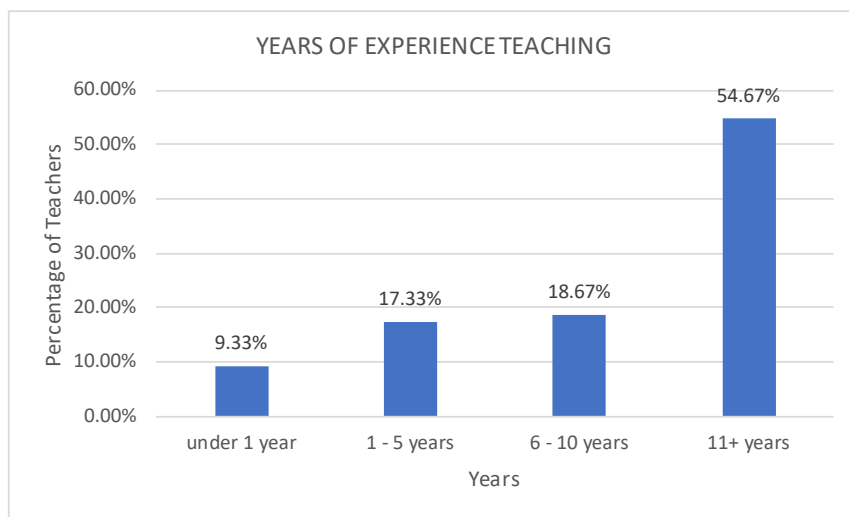


Figure 4.1 Shows years of teacher experience in classroom

Teachers were asked how long they had been teaching in their current classroom with 29 out of 75 responding 1-5 years. This was the highest percentage at 38.67%, with a quantity of 19 (25.33%) under 1 year and 16 (21.33%) between 6-10 years in their current classroom.

Teachers were recruited from public and private schools with 46 out of 75 teaching in public schools and 27 in private schools. Two respondents answered “other” with one specifying a lab school and the second ministry. These both could technically be placed in one of the other categories, however, it does not significantly impact the results (refer to Figure 4.2).

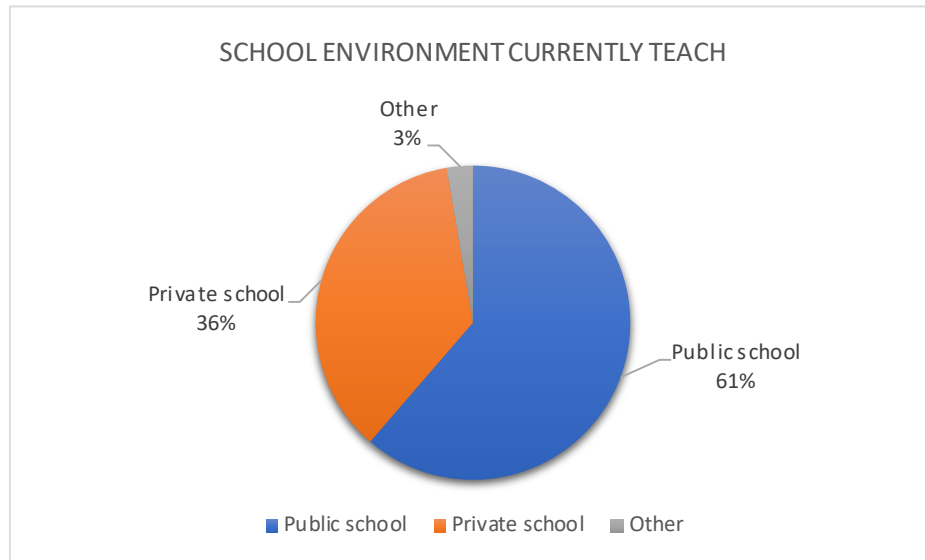


Figure 4.2 Shows percentage of teachers and type of school they currently teach

The recruited population teach levels Pre-K through 12. Most responses were received from Lower Elementary (28%); Upper Elementary (21.33%) and Middle School (21.33%). Kindergarten and High School had the lowest number of respondents, quantity of 4 and 6 respectively; and Pre-K had a quantity of 12 (16%). Refer to Figure 4.3.

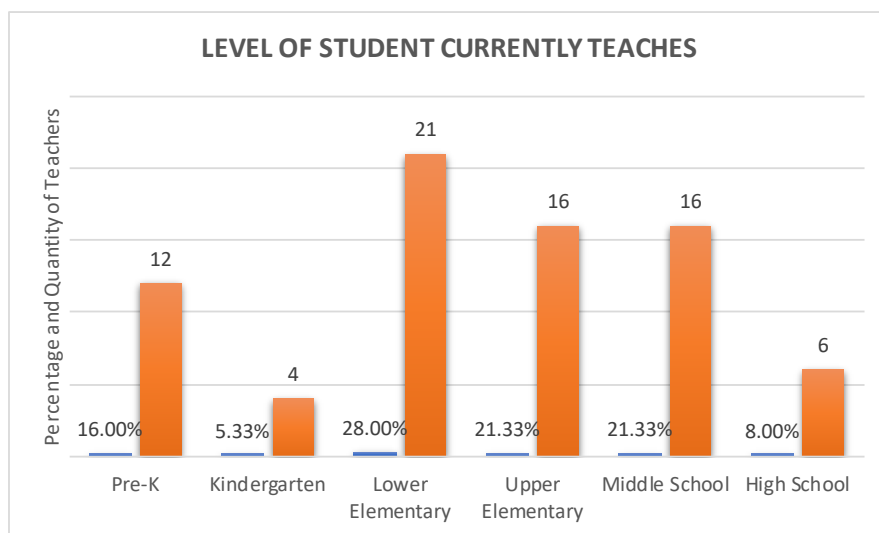


Figure 4.3 Shows percentage and quantity of teachers and level currently teaching

Existing Classroom Lighting

Teachers were asked about the type of overhead lighting, fluorescent or LED, within their current classroom. Most indicated having fluorescent lighting, a quantity of 62 of 75, and only 2 indicated having LED in their classroom. A quantity of 8 did not know what type of lighting they currently had. Three responded as “other”, with 1 indicating that they have a mix of fluorescent and LED, due to their school retrofitting existing fluorescent fixtures with LED when tubes need replacing (refer to Table 4.4)

The type of fixture and lens implemented within a built environment can impact the distribution of light and the teacher’s perception. Images of lens types were used to assist with correct responses and included fixtures with acrylic, parabolic, and troffer prismatic. Most teachers, 37 of 75 or 50%, indicated that acrylic lenses were in their current classroom. Troffer prismatic were the next highest quantity at 16 (21.6 %), and parabolic at a quantity of 10 (13.51%). A quantity of 9 indicated they “didn’t know.” A quantity of 2 indicated “other, please explain” (refer to Figure 4.5).

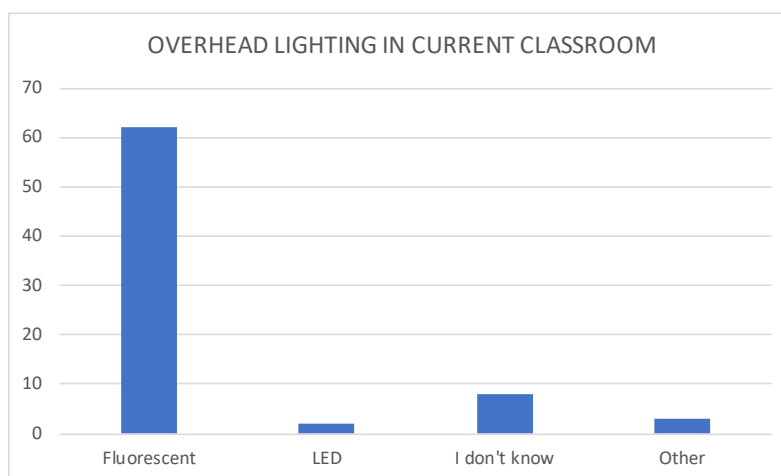


Figure 4.4 Teacher response number and type of overhead lighting in current classrooms

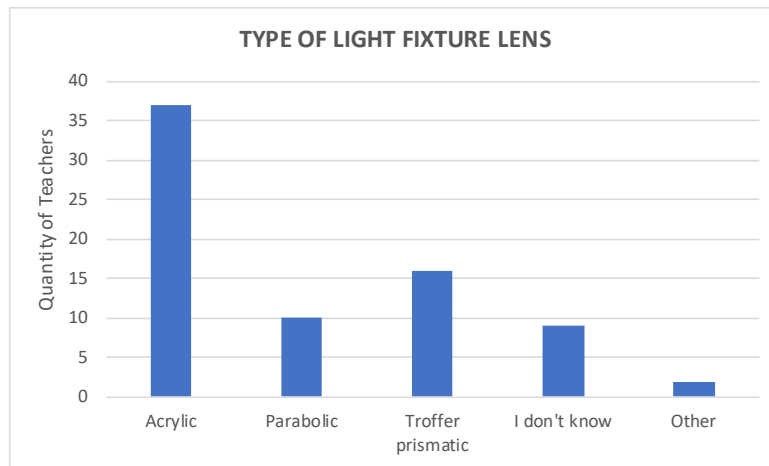


Figure 4.5 Type of light fixture lens in current classrooms of teacher respondents

Natural daylight and other types of artificial light can also impact a classroom and student attitudes and behaviors, especially daylight from windows and skylights. Teachers were asked about other types of lighting used within their classroom. Most classrooms had windows with a quantity of 64 or 62.75% of respondents. The use of desk lamps was the next highest response with a quantity of 14 at 13.73%.

Lighting and Affect: Attitude, Mood and Alertness

Studies by Slegers, et al., (2012) and Mott, et al., (2012) illustrated emotional/mood responses based on different kelvin temperature, with bluer/higher kelvin temperatures emoting alertness, focus, and arousal; and lower kelvin for calmness. Questions incorporating classroom images with different kelvin temperatures were used to rate teacher insight and perceptions as to the impact on student attitude, mood, and motivation.

Four questions addressed alertness and energy/arousal. The first question asked teachers to select the classroom they perceived best for enhancing student alertness. Two images of the same classroom, one with LED 4200K lighting and the second with Fluorescent 3200K lighting

were used. The classroom illustrating the higher kelvin LED (4200K) lighting was perceived as best for enhancing alertness by 44 of 72 respondents or 61.11% (refer to Table 4.1). Three additional questions provided single images of classrooms illustrating different kelvin temperatures; 4200K, 3500K and 6500K respectively. The classroom with 4200K was selected by 50.68% as best for encouraging energy/arousal or moving and interacting (refer to Table 4.2).

Table 4.1 Percentage of teachers selecting LED 4200K classroom image versus fluorescent 3200K for enhancing alertness

Answer	%
LED 4200K	61.11%
Fluorescent 3200	29.17%
Neither, please explain	9.72%
Total	100%

Table 4.2 Percentage of teachers selecting 4200K classroom image for encouraging alertness-move/interact

Answer	%
Focus: Sit and listen	28.77%
Alertness: Move and interact	50.68%
Calm: Relax and rest	4.11%
None of the above	10.96%
Other, please specify	5.48%
Total	100%

Four questions also addressed calmness and quiet/restfulness. The first question used the same classroom image with different kelvin temperatures. Teachers perceived the lower 3000K image best for encouraging calmness versus 5000K (refer to Table 4.3). Three additional questions used single images of classrooms illustrating different CCT; 4200K, 3500K and 6500K

respectively. The image illustrating 3500K, had mixed results, suggesting no significance.

Although the largest percentage (33.33%) identified this classroom lighting best for encouraging calm (relax and rest), 30.56% identified it best for alertness/arousal (move and interact) and 30.56% for focus (sit and listen) (refer to Table 4.4).

Table 4.3 Percentage of teachers selecting 3000K classroom image versus 5000K for enhancing calmness

Answer	%
LED 3000K	62.16%
LED 5000K	31.08%
Neither, please explain	6.76%
Total	100%

Table 4.4 Shows mixed results for teacher selection of affect or engagement for 3500K classroom

Answer	%
Focus: Sit and listen	30.56%
Alertness: Move and interact	30.56%
Calm: Relax and rest	33.33%
None of the above	4.17%
Other, please specify	1.39%
Total	100%

Lighting and Engagement: Attention and On-Task Behavior

Five questions addressed engagement and on-task/off-task behaviors by using classroom images with different kelvin temperature. The first question asked teachers to select the classroom they perceived best for encouraging focus during testing. Two images of the same classroom, one with 5000K lighting and the second with 6500K lighting were used, both are

considered high CCT per definition. The classroom illustrating the 6500K lighting was perceived as best for focusing during testing by 40 of 73 respondents or 54.79%, while the 5000K classroom was selected by 28 of 73 respondents or 38.36% (refer to Table 4.5). A second question asked teachers to select the classroom they perceived best for encouraging on-task behavior. Two images of another classroom, one image with 3500K and second image with 5000K were used. In this instance, most teachers (72.60%) selected the classroom with 3500K best for on-task behavior (refer to Table 4.6). Three additional questions provided single images of classrooms illustrating different kelvin temperatures; 4200K, 3500K and 6500K respectively. The image illustrating 6500K was selected by 52.11% for encouraging on-task behavior of sit and listen (refer to Table 4.7).

Table 4.5 Percentage of teachers selecting 6500K classroom image versus 5000K for enhancing focus during testing

Answer	%
5000K	38.36%
6500K	54.79%
Neither, please explain	6.85%
Total	100%

Table 4.6 Percentage of teachers selecting 3500K classroom image versus 5000K for encouraging on-task behavior

Answer	%
3500K	72.60%
5000K	16.44%
Neither, please explain	10.96%
Total	100%

Table 4.7 Percentage of teachers selecting 6500K classroom image for encouraging focus

Answer	%
Focus: Sit and listen	52.11%
Alertness: Move and interact	25.35%
Calm: Relax and rest	2.82%
None of the above	14.08%
Other, please specify	5.63%
Total	100%

Teachers were asked to respond to off-task behaviors they observe and perceive as being related to lighting problems in their classroom with a 5-point Likert rating scale of “never/rarely/sometimes/often/always.” The off-task behaviors included: 1) fidget in seat, unable to sit still; 2) not involved, appear to be daydreaming; 3) appear tired or lethargic; 4) become agitated or frustrated; 5) overtly act out, not attending to lesson. Most teachers responded as “sometimes, rarely, or never.” The highest response for “sometimes” was 28 out of 72 teachers (38%) for the off-behavior “not involved/appear to be daydreaming”; with “fidget in seat/unable to sit still”, and “appear tired or lethargic”, both with 23 out of 72 teachers or 31.94%. The percentage of responses for “often” or “always” ranged from 0% - 9.72% (refer to Figure 4.6).

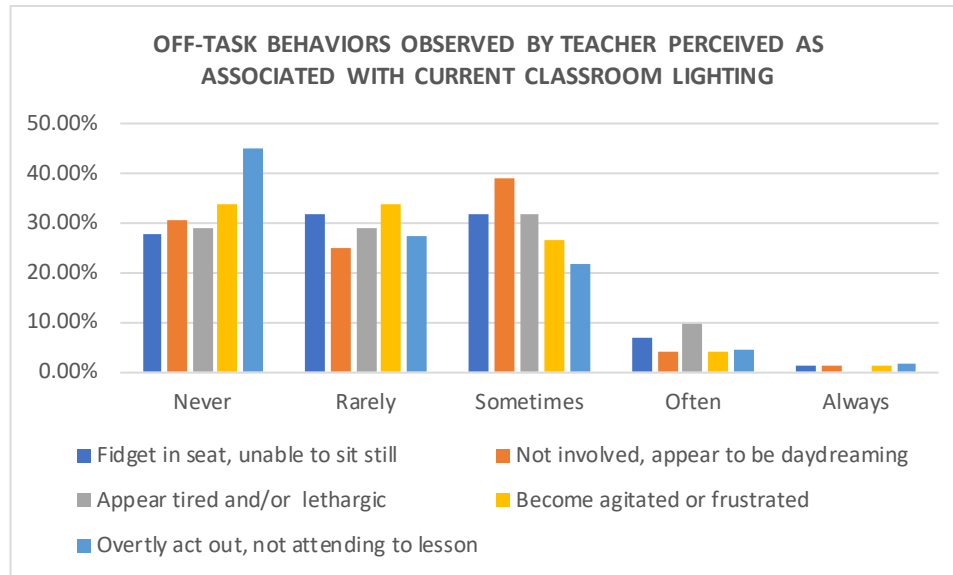


Figure 4.6 Percentage of teachers who perceive current classroom lighting impacts observed off-task behaviors of students

Lighting and Health and Well-Being: Sounds and Flicker

One of the complaints of fluorescent lamps is the buzzing or humming sound they can produce due to the ballast. Fluorescents lamps often flicker when being turned on or if the tube is close to burning out. Teachers were asked if they perceived negative issues with existing lighting in their classroom regarding 1) light glares off objects, 2) lights flash, 3) lights flicker, 4) lighting is unusually bright. There wasn't a significant response of agreement regarding a perceived issue with lights flashing or flickering. Light glare and unusual brightness of lighting did have a higher response of agreement and significance with a quantity of 10 (13.51%) "strongly agree" and 35 (47.30%) - "somewhat agree." Teachers rated the issue of "lighting being unusually bright" with a quantity of 12 (16.44%) "strongly agree" and 22 (30.14%) "somewhat agree" (refer to Figure 4.7).

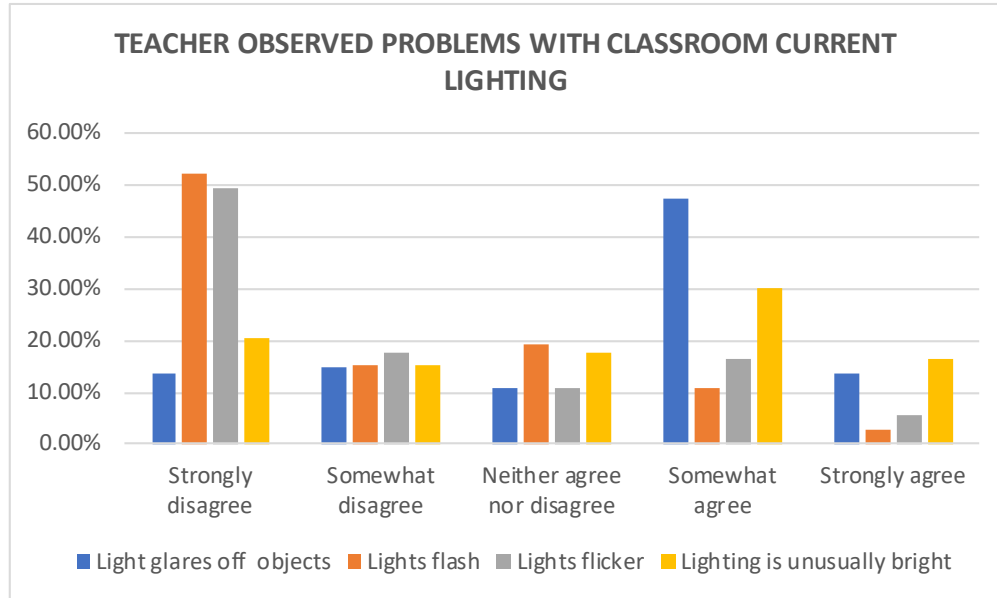


Figure 4.7 Percentage of teachers observing negative issues with existing classroom lighting

Teachers were asked to rate what extent they perceive the following lighting issues impact students: 1) notice the hum of electronic noise from the light fixtures; 2) are bothered by the hum of the lights; 3) perceive the intensity or brightness of lights; 4) are bothered by the intensity or brightness of the lights; 5) perceive the glare of the lights; 6) are bothered by the glare of the lights. The leader scale was 0 – 10 with 0 = “None”, 5 = “Some” and 10 = “A lot.” The mean calculations and standard deviations ranged from lowest 1.84 mean /2.38 standard deviation (students are bothered by the hum of the lights) to 3.61 mean, 2.94 standard deviation (students are bothered by the glare of the lights). These findings suggest no significance of perceived student impact (refer to Figure 4.8)

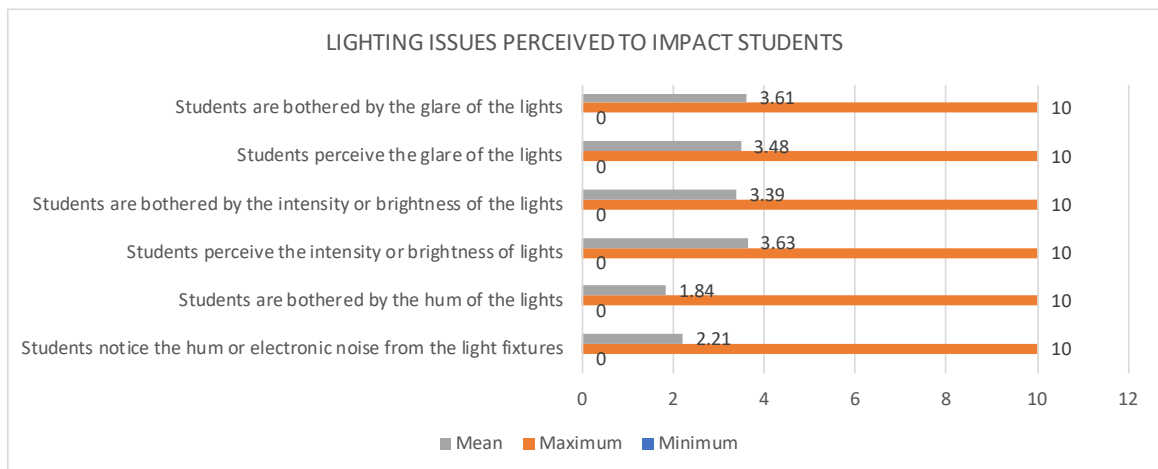


Figure 4.8 Mean values of lighting issues and teacher perceived impact on students

Light Levels and Behavior

Research has shown that adjusting light levels within a classroom can affect children's behavior and is a tool often used by teachers. Teachers were asked if they adjust the light level in their classroom to enhance the environment for students. Significantly, 81.08% responded "yes," with a quantity of 60 out of 74 responses. A quantity of 5 (6.75%) responded "no," and 9 (12.16%) indicated they do not have the ability to adjust the light level (refer to Figure 4.9).

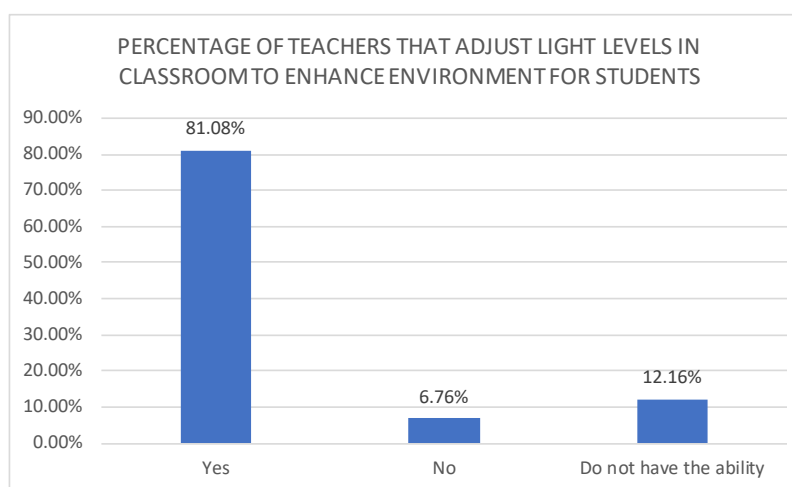


Figure 4.9 Percentage of teachers that adjust classroom light level to enhance environment

Teachers were asked during what times of day they adjust light levels in their classroom with a quantity of 43 (33.86%) responding “during morning hours” and a quantity of 35 (27.56%) during afternoon hours (refer to Figure 4.10). Teachers were also asked during which activities they adjusted light levels in their classroom. The top two responses were a quantity of 55 (31.98%) “during viewing of digital display” and a quantity of 41 (23.84%) during quiet time. A quantity of 4 of the 10 “other” responses indicated turning lights off and only using daylight to create calm and to quiet students down (refer to Figure 4.11).

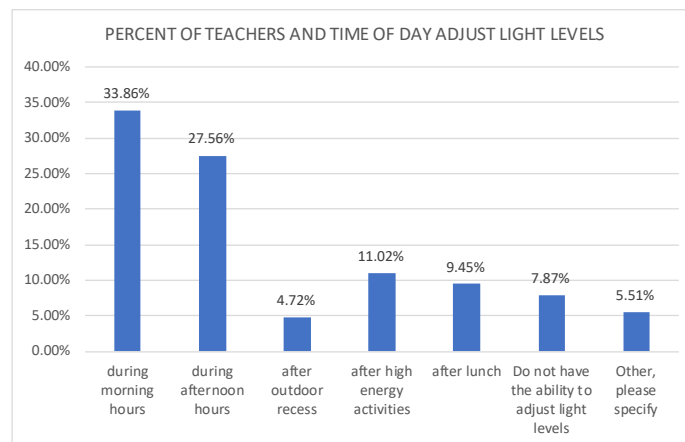


Figure 4.10 Shows percentage of teachers adjusting light levels during specific times of day

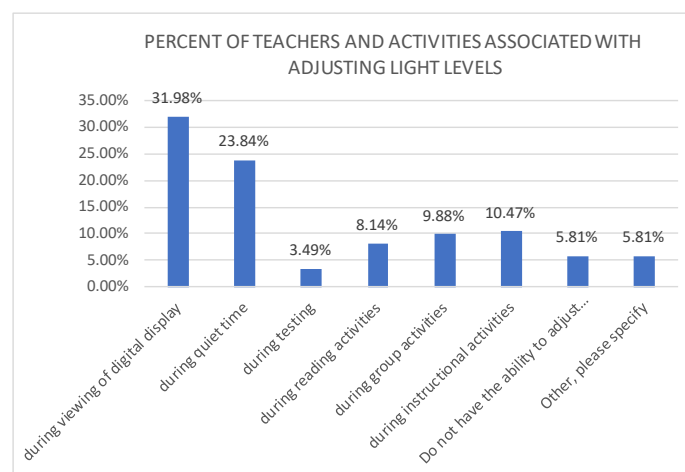


Figure 4.11 Shows percentage of teachers adjusting light levels for activities

Comments by Participants

An opportunity was provided for participant comments regarding their insights and perceptions of lighting in classrooms and the impact on student attitudes and behavior. Most comments can be placed in 3 categories: 1) ability to adjust light levels for activities and engagement, 2) affect with regards to attitude/mood, and 3) health and well-being. Noted in parenthesis is school level the respondent currently teaches.

Comments regarding adjusting light levels included:

- 1) ...I feel the best lighting is the most natural lighting you can get. That could be awesome LEDs with dimmer switches and/or tons of sunlight with curtains. Everyone is affected differently by color and intensity of light. It all depends on your kids and what activities you are doing. (PreK)
- 2) Change the lighting like you change the activities. It helps keep the students and you engaged and on your toes. (High School)
- 3) I have a lot of windows and natural light in my room. Students always ask to turn the lights off - the overhead lights and iPad screens really affect some students. (Middle School)
- 4) Wish I could dim the lights instead of just turn them off. Sometimes the sunlight is so bright coming in the window that it's hard to see. (Upper Elementary)

Comments regarding affect of attitude and mood, and one comment addressing engagement included:

- 1) If I have to turn the lights on because the day is simply too dark for enough natural light, the kids complain loudly. I would say it absolutely impacts the mood and tone of my classroom. (Middle School)

- 2) I am a school librarian and love low lighting. I had the bulbs, above my desk, removed.

In the large study rooms, we have lots of natural light. My preference is to turn off the overhead lights for a more calming environment. (High School)

- 3) Lowering lighting calms students down. (Lower Elementary)
- 4) Brighter, clearer lighting may enhance a student's spirit. (Middle School)
- 5) I think the blue light covers in my room provide a calming effect in my classroom and allows the kids to better focus and concentrate on the task at hand. (Lower Elementary)
- 6) Lighting can also make children grumpier and not wanting to be in the classroom. (PreK)

Comments regarding impact on health and well-being included:

- 1) Intense artificial light can increase anxiety, interfere with concentration levels even cause headaches. I have experienced this personally in all day meetings in a school with all LED lighting. (Upper Elementary)
- 2) Harsh lighting bothers everyone. Diffused light helps if not too diffused. (Middle School)
- 3) I have had to mute the fluorescent lighting for students with autism. (Lower Elementary)

Summary

Significant and mixed results from the teacher survey were found regarding the impact of lighting on mood, attitude, and engagement. There was also mixed support for the hypothesis that higher correlated color temperature LED lighting versus fluorescent lighting within a classroom positively impacts perceived attitudes and behaviors. The most significant outcomes are:

- Impact on positive mood, alertness, and energy:

Most teachers selected classroom images with higher kelvin temperature as encouraging positive affect, alertness, and energy. With 61.11% selecting

4200K over 3200K and 50.68% selecting another image illustrating 4200K for energy level of move and interact.

- Impact on calm and restful mood:

Most teachers selected the classroom image with lower kelvin temperature as encouraging calm. 3000K lighting was selected by 62.16% of respondents over the same classroom image with 5000K. A separate individual classroom image at 3500K received mixed results with only 33.33% response as encouraging relaxation and rest, and 30.56% responding as encouraging engagement or energy. This suggests that the difference of 500K may impact perceived mood, however, these results cannot be considered significant.

- Impact on student engagement and on-task/off-task behaviors:

Mixed results were found regarding questions on focus and on-task behaviors. Most teachers selected the classroom image with higher kelvin temperature when asked about encouraging student focus with 54.79% selecting 6500K over 5000K at 38.36%; and 52.11% selected a separate image illustrating 6500K as best for encouraging student on-task behavior of sitting and listening.

However, when asked about on-task behaviors when showing a second comparison classroom a significant percentage selected 3500K (72.60%) over 5000K (16.44%). Also, teacher responses to perceived student off-task behaviors due to lighting issues using a 5-point Likert scale of “never, rarely, sometimes, often, always,” were not significant. The highest responses were “Sometimes”, 38.89% “fidget in seat”, and 31.94% for both “not involved, appear to be daydreaming” and “appear tired/lethargic.”

- Impact on health and well-being:

Most teachers, 82.67%, responded as currently having fluorescent lighting within their classroom. The issue of glare of lighting off objects and brightness of lights did not result in a significant response, with 47.30 % selecting “somewhat agree” and 13.51% “strongly agree.” There were also not significant results regarding the impact of sound and flickering from fluorescent lights. A quantity of 3 out of 19 teachers provided comments addressing concerns and insights regarding lighting and well-being.

- Impact of adjusting light levels in classroom:

Most teachers, 81.08%, indicated they adjust light levels within their classroom to impact mood, attention, and engagement regarding specific activities and times of day. There was a quantity of 19 responses to the open-ended final question to comment on their insights and perceptions of how lighting impacts their students and classroom environment. Thirteen of the 19, 68.4%, responses addressed the importance of adjusting light levels to encourage engagement, positive mood, and well-being.

CHAPTER 5

DISCUSSION

The purpose of this study was to examine insights and perceptions regarding attitudes and behaviors associated with classroom lighting, specifically the impact of fluorescent versus LED high correlated color temperature (CCT) lighting on students. This chapter will outline findings from the questionnaire based on teacher insights and perceptions of classroom lighting compared with the literature review regarding: 1) impact on positive mood, attitudes, and alertness of students, 2) impact on student engagement and on-task/off-task behaviors and 3) impact on well-being.

Impact on positive mood, attitudes, and alertness of students

Much theoretical research has focused on our body's natural clock, or circadian rhythm which regulates our sleep/wake cycle; indicating our body responds/awakens to bluish light as experienced in morning hours, and warmer light causes the brain to release melatonin which prompts us to relax and prepare our bodies to sleep. (Govén, et al, 2009; Kuller, et al, 2006). Studies by Slegers, et al., (2012) and Mott, et al., (2012) illustrated emotional/mood responses based on different kelvin temperature, with bluer/higher kelvin temperatures emoting alertness, focus, and arousal; and lower warmer kelvin for calmness. Most teachers selected classroom images with higher kelvin temperature as encouraging positive attitude, alertness, and energy.

With 61.11% selecting 4200K for alertness over 3200K, and 50.68% selecting 4200K for activity of move and interact.

Survey results were mixed regarding impact of kelvin temperature on encouraging calm. The classroom illustrating 3000K was selected by most teachers (62.16%) for enhancing calmness over the classroom using 5000K. Another image illustrating 3500K had mixed results with the largest percentage (33.33%) identifying this classroom lighting best for encouraging restfulness (relax and rest), 30.56% identified it best for both activeness/arousal (move and interact) and focus (sit and listen). These results may support the findings of Slegers, et al., (2012) and Mott, et al., (2012) that kelvin temperature 3000 and lower can induce calmness; and that the difference of 500K is perceived as cooler and whiter, and not as calming. However, these results cannot be considered significant.

Impact on student engagement and on-task/off-task behaviors

Hawes, et al., (2011) and Sleeper, et al, (2012) found that LED lighting at a higher correlated color temperature has a perceived positive impact on behaviors during activities that require focus such as taking a test. Hoffmann et al. (2008) demonstrated that 6500K compared to 4000K enhanced levels of attention and concentration (Hawes, 2010). Most teachers selected the LED 6500K classroom for on-task behaviors and engagement. With 54.79% selecting 6500K over 5000K for encouraging focus during testing, and 52.11% selected a separate image illustrating 6500K as best for encouraging on-task behavior of sitting and listening. However, a third image with a lower color temperature image of 3500K was selected by most for encouraging “on-task behaviors” over the 5000K image, suggesting no significance was found. The results regarding teacher perceptions of how lighting impacts student off-task behaviors also did not provide significant findings. Slegers, et al, (2012) found on average that student

concentration increased with 6500K, but findings also indicated improved concentration may be based on grade level, with grade 4 students more affected than grade 6.

Impact on health and well-being

Most teachers, 82.67%, responded as currently having fluorescent lighting within their classroom. Many studies have found that normally functioning fluorescents can be a source of flicker and have biological effects such as a general feeling of discomfort, illness, headaches, eye strain (IEEE, 2010) and reduced speed of visual search and performance (Veitch & McColl, 1995). The perceived impact of sounds and flickering on student comfort and well-being were mixed and not significant. The “glare of lighting off objects” was rated highest as a perceived problem, with 47.30% rating as “somewhat agree” and only 13.51% as “strongly agree.” The next highest rated problem was “lighting is unusually bright” with a response rate of 30.14% “somewhat agree” and 16.44% as “strongly agree.”

Impact of adjusting light levels for engagement, affect and well-being

Most teachers, 81.08%, indicated they adjust light levels within their classroom to impact mood, attention, and engagement regarding specific activities and times of day. A quantity of 19 additional comments were received regarding teacher insights and perceptions of the impact of classroom lighting. Thirteen of the 19, 68.4%, responses addressed the importance of adjusting light levels to encourage engagement, positive mood, and well-being. These results support findings by Slegers, et al, (2012), Mott, et al, (2012), and Hawes, et al, (2011) that dynamic or tunable lighting within the classroom may benefit children’s behaviors and performance. This concept would need to be further studied as to whether it is the “amount of light” or the correlated color temperature that affects perceived attitude and behavior.

CHAPTER 6

CONCLUSION, LIMITATIONS AND RECOMMENDATIONS

The purpose of this study was to examine perceptions, attitudes and behaviors associated with classroom lighting, specifically the impact of fluorescent versus LED high correlated color temperature (CCT) lighting on students. Lighting within the built environment can have an impact on the well-being, behavior, and performance of humans (Smolder & de Kort, 2014). Many studies have examined fluorescent and LED lighting at various correlated color temperatures within work environments and classrooms.

This study collected survey data based on teacher insights and perceptions with results supporting the perception of higher correlated color temperature lighting positively impacting alertness, attitude, and energy level. Findings also supported the ability to change light levels throughout the school day to positively impact student engagement and mood. There were mixed results regarding higher correlated color temperature impacting attention and on-task/off-task behaviors. Results regarding the impact of sound and flickering from fluorescent lights were not significant. The issue of “lights glaring off objects” was selected as “somewhat agree” by the highest percentage of teachers surveyed.

The study presents limitations due to the teacher survey is based in self-reported insights and perceptions. Also, classroom images utilized may be subjective due to the inability to

control consistency of the computer monitor color display used by participants. It is suggested that further research and other methodologies need to occur to better understand the impact of higher correlated color temperature LED versus fluorescent lighting on students in the classroom. These methodologies should include controlled laboratory and classroom settings with monitored observation, directly measuring behaviors and attitudes. Also, the concept of dynamic or tunable lighting has limited empirical research and needs to be further studied based on its impact in the classroom and establishing guidelines for use. Understanding the impact of classroom lighting on student behavior, attitudes and engagement is important for ensuring their academic success, as well as physical, emotional, and cognitive well-being.

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APPENDIX A



Office of Research Integrity
Institutional Review Board (IRB)
2000 University Avenue
Muncie, IN 47306-0155
Phone: 765-285-5070

DATE: April 5, 2018
TO: Brenda Morrow
FROM: Ball State University IRB
RE: IRB protocol # 1213195-1
TITLE: The Impact of Fluorescent and LED Lighting on Student Attitudes and Behavior in the Classroom
SUBMISSION TYPE: New Project

ACTION: APPROVED
DECISION DATE: April 5, 2018
REVIEW TYPE: **EXEMPT**

The Institutional Review Board reviewed your protocol on April 5, 2018 and has determined the procedures you have proposed are appropriate for exemption under the federal regulations. As such, there will be no further review of your protocol, and you are cleared to proceed with the procedures outlined in your protocol. As an exempt study, there is no requirement for continuing review. Your protocol will remain on file with the IRB as a matter of record.

Exempt Categories:

	Category 1: Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
X	Category 2: Research involving the use of educational test (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior
	Category 3: Research involving the use of educational test (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under category 2, if: (i) the human subjects are elected or appointed officials or candidates for public office; or (ii) Federal statute(s) require(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

	Category 4: Research involving the collection of study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available or
	if the information is recorded by the investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects.
	Category 5: Research and demonstration projects which are conducted by or subject to the approval of Department or agency heads, and which are designed to study, evaluate or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in methods or levels of payment for benefits or services under these programs.
	Category 6: Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed or (ii) if a food is consumed which contains a food ingredient at or below the level and for a use found to be safe, by the Food and Drug Administration or approved by the Environmental Protection Agency or the Food Safety and Inspection Service of the U.S. Department of Agriculture.

Editorial Notes:

1. Approve

While your project does not require continuing review, it is the responsibility of the P.I. (and, if applicable, faculty supervisor) to inform the IRB if the procedures presented in this protocol are to be modified or if problems related to human research participants arise in connection with this project.

Any procedural modifications must be evaluated by the IRB before being implemented, as some modifications may change the review status of this project. Please contact (ORI Staff) if you are unsure whether your proposed modification requires review or have any questions. Proposed modifications should be addressed in writing and submitted electronically to the IRB (<http://www.bsu.edu/irb>) for review. Please reference the above IRB protocol number in any communication to the IRB regarding this project.

Reminder: Even though your study is exempt from the relevant federal regulations of the Common Rule (45 CFR 46, subpart A), you and your research team are not exempt from ethical research practices and should therefore employ all protections for your participants and their data which are appropriate to your project.

D. Clark Dickin, PhD/Chair
Institutional Review Board

Christopher Mangelli, JD, MS, MEd, CIP/
Director
Office of Research Integrity

APPENDIX B

Recruitment Email and Introductory Script for Qualified Teachers

IRB Protocol # 1213195-1

The Impact of Fluorescent and LED Lighting on Student Attitudes and Behavior in the Classroom

Hello,

You are invited to participate in the on-line survey, "Teacher Insights: Impact of Lighting on Student Attitudes and Behavior in the Classroom." (IRB # 1213195-1) I'm a graduate student of Interior Design at Ball State University and my research focuses on creating healthy built environments, with the goal of further understanding the impact of LED and fluorescent lighting on student attitudes and behavior in the classroom.

Participants must be 18 years of age and have taught a minimum of 12 weeks in the classroom, teach between levels PreK-12, are a full-time teacher, practicum teacher, teacher aide or full time building substitute teacher.

Participation is completely voluntary, and all responses will be kept anonymous. The survey will take approximately 5-10 minutes. You will be asked questions regarding your perceptions and insights regarding the topic listed above.

Your participation is greatly appreciated. Please follow the link below to participate in the survey.

https://bsu.qualtrics.com/jfe/form/SV_dd7RQKUnoKQhVP

Thank you,

Brenda Morrow, Principal Investigator, blmorrow@bsu.edu

Dr. Shireen Kanakri, Faculty Advisor, smkanakri@bsu.edu

Teacher Insights: Impact of Lighting on Student Attitudes and Behavior in the Classroom

Thank you for agreeing to complete this brief survey about the lighting environment in classrooms. Research indicates lighting conditions significantly impact student attitudes and behavior. Your answers on the following questions will help interior designers develop spaces to enhance environments for learning.

Q1. Gender of rater

- ☐ Female
- ☐ Male
- ☐ Other
- ☐ Do not wish to respond

Q2. How long have you taught in a classroom setting?

- ☐ under 1 year
- ☐ 1 - 5 years
- ☐ 6 - 10 years
- ☐ 11+ years

Q3. How long have you taught in your current classroom/building?

- ☐ under 1 year
- ☐ 1 - 5 years
- ☐ 6 - 10 years
- ☐ 11+ years

Q4. In what type of school environment do you currently teach?

- ☐ Public school
- ☐ Private school
- ☐ Other (please specify) _____

Q5. What level of student do you currently teach?

- ☐ Pre-K
- ☐ Kindergarten
- ☐ Lower Elementary
- ☐ Upper Elementary
- ☐ Middle School
- ☐ High School

Q6. What overhead lighting or lamp type is used in your current classroom for general lighting?

- ☐ Fluorescent
- ☐ LED
- ☐ I don't know
- ☐ Other, please explain: _____

Q7. What type of lens covers the overhead light fixtures?

☐ Acrylic



Image (Philips, 2018)

☐ Parabolic, small or large cube



Image (LEDTRONICS, 2018)

☐ Troffer prismatic



Image (Lithonia, 2018)

☐ I don't know

☐ Other, please explain _____

Q8. What other lighting or lamp types are used in your classroom (select all that apply):

☐ Windows

☐ Sky lights

☐ Floor lamps

☐ Desk lamps

☐ Incandescent fixtures







☐ Other, please explain: _____

☐ I don't know

Q9. Are any of these issues present with the lighting within your classroom?

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
Light glares off objects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lights flash	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lights flicker	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lighting is unusually bright	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q10. Please indicate the extent to which the following lighting issues impact your students.

	None 0	1	2	3	4	Some 5	6	7	8	A Lot 9	10
Students notice the hum or electronic noise from the light fixtures											
Students are bothered by the hum of the lights											
Students perceive the intensity or brightness of lights											
Students are bothered by the intensity or brightness of the lights											
Students perceive the glare of the lights											
Students are bothered by the glare of the lights											

Q11. Please indicate which behaviors you observe most frequently by students in response to perceived lighting problems in the classroom environment.

	Never	Rarely	Sometimes	Often	Always
Fidget in seat, unable to sit still	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Not involved, appear to be daydreaming	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Appear tired and/or lethargic	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Become agitated or frustrated	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Overtly act out, not attending to lesson	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other, please specify	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other, please specify	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q12. Do you ever adjust the light level in your classroom to enhance the environment for students?

- ☐ Yes
- ☐ No
- ☐ Do not have the ability

Q13. Please indicate during which (if any) of the following activities you adjust the light level in your classroom (mark all that apply)

- ☐ during viewing of digital display
- ☐ during quiet time
- ☐ during testing
- ☐ during reading activities
- ☐ during group activities
- ☐ during instructional activities
- ☐ Do not have the ability to adjust light levels
- ☐ Other, please specify _____
- ☐ Other, please specify _____

Q14. Please indicate which (if any) of the following times of day you adjust the light level in your classroom?

- ☐ during morning hours
- ☐ during afternoon hours
- ☐ after outdoor recess
- ☐ after high energy activities
- ☐ after lunch
- ☐ Do not have the ability to adjust light levels
- ☐ Other, please specify _____
- ☐ Other, please specify _____

The following images illustrate the same classroom implemented with different lighting. Please select which statement best describes your perception of how student attitudes or behavior would be impacted.

Q15. Select the classroom lighting environment you perceive would enhance student alertness.

☐



☐



Images (Eco Lighting Designs, 2017)

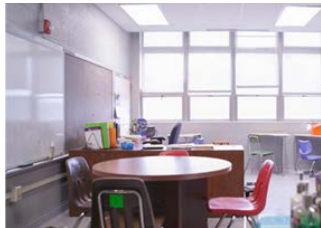
☐ Neither, please explain _____

Q16. Select the classroom lighting environment you perceive would enhance positive mood of students.

☐



☐



Images (Energy Focus, n.d.)

☐ Neither, please explain _____

Q17. Select the classroom lighting environment you perceive would enhance focus during testing.

☐



☐

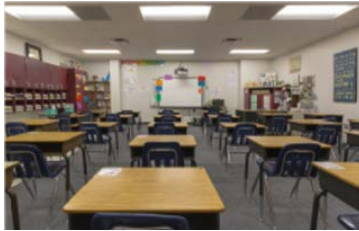


Images (Spark Lighting, 2017)

☐ Neither, please explain _____

Q18. Select the classroom lighting environment you perceive would encourage staying on-task.

☐



☐



Images (LCA, 2017)

☐ Neither, please explain _____

Q19. Select the classroom lighting environment which you perceive would enhance student calmness.

☐



☐



Images (Philips School Vision, 2017)

☐ Neither, please explain _____

The following images illustrate different classrooms and lighting. Please select which statement best describes your perception of how student attitudes or behavior would be impacted.



Image (Green Power Projects, 2017)

Q20. The classroom lighting illustrated above encourages students to:

☐ Sit and listen

☐ Move and interact

☐ Relax and rest

☐ None of the above

☐ Other, please specify _____



Image (3500K, n.d.)

Q21. The lighting illustrated in the above classroom encourages students to:

- ☐ Sit and listen
- ☐ Move and interact
- ☐ Relax and rest
- ☐ None of the above
- ☐ Other, please specify _____



Image (Philips School Vision, 2017)

Q22. The lighting illustrated in the above classroom encourages students to:

- ☐ Sit and listen
- ☐ Move and interact
- ☐ Relax and rest
- ☐ None of the above
- ☐ Other, please specify _____

Q23. Is there anything else you would like to tell us about the lighting in your classroom and how you perceive it impacts student attitudes or behavior?